

Planet Discovery & Orbit Estimation

Robert Brown

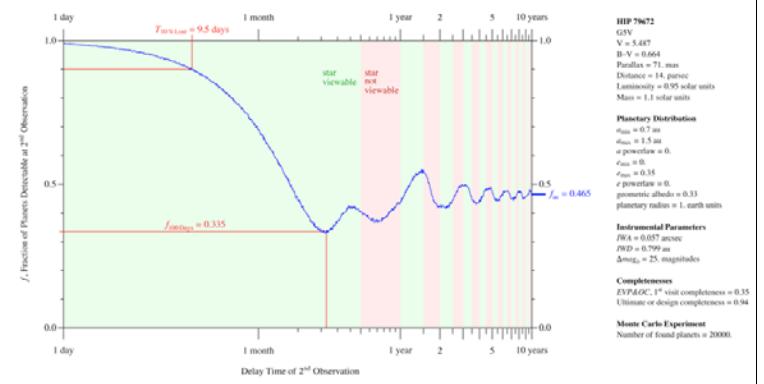
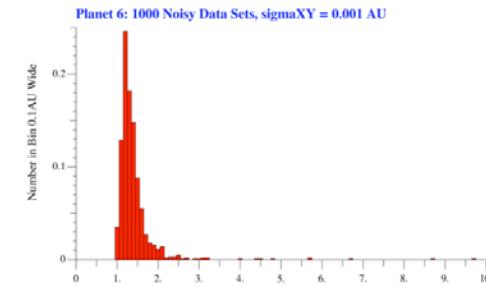
with

Stuart Shaklan

Sarah Hunyadi

Steve Pravdo

18 May 2007



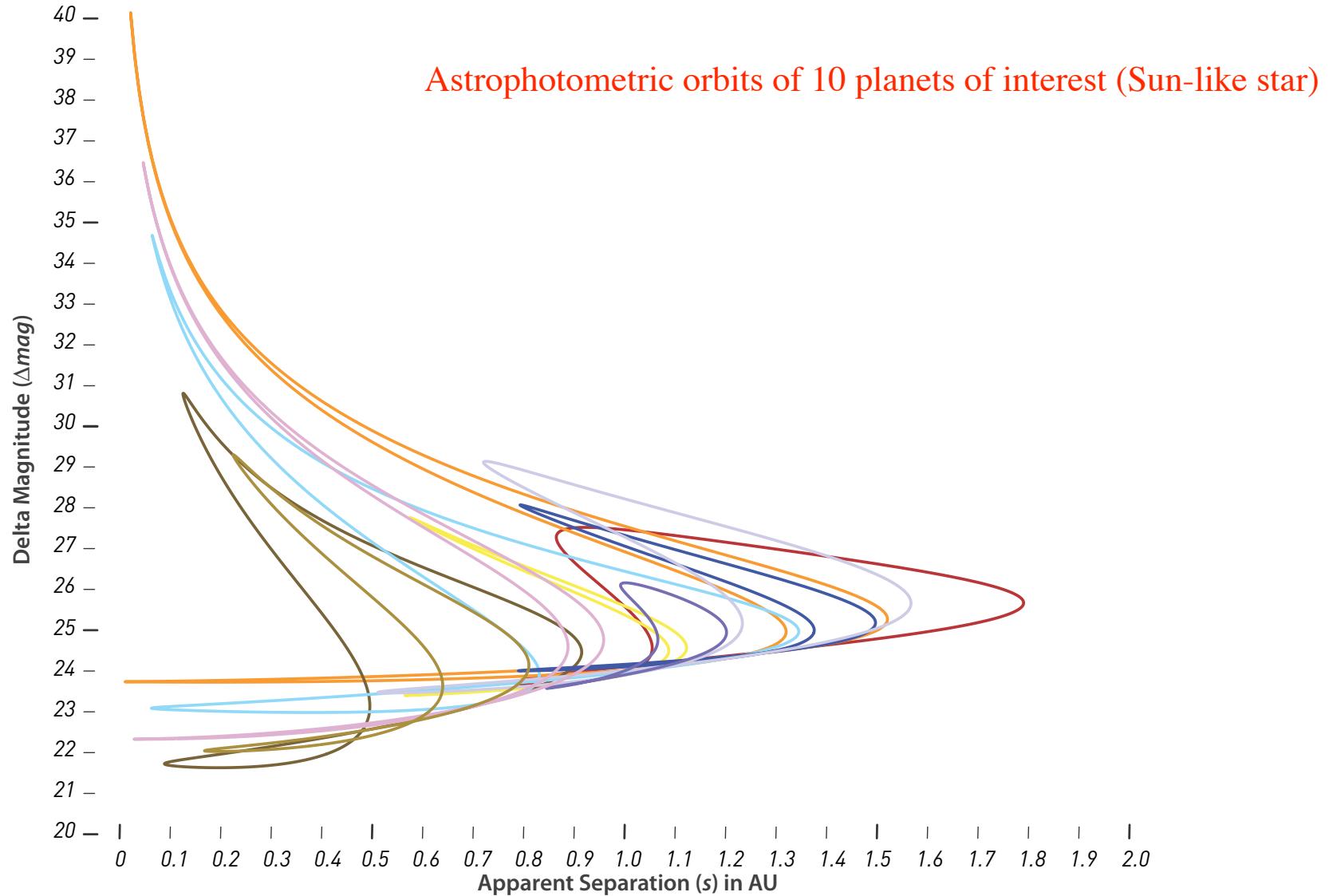
Planets of Interest

Parameter	Original	Units	Rule
Semimajor axis (a)	$0.7\sqrt{L} - 1.5\sqrt{L}$	au	uniform
Eccentricity (e)	0.0–0.35		uniform
Euler angle #1 (ψ)	$0 - 2\pi$		uniform
Euler angle #2 (θ)	$0 - \pi$		uniform ¹
Euler angle #3 (ϕ)	$0 - 2\pi$		uniform
Initial phase (v_0)	$0 - 2\pi$		uniform
Period (T_{ORB})	$365.25 a^{1.5} m_{\text{STAR}}^{-0.5}$	days	computed
Effective planetary area ($p \pi R^2$)	0.33	πR_{\oplus}^2	fixed value
Phase function	$\frac{\sin\beta + (\pi - \beta) \cos\beta}{\pi}$		fixed function ²

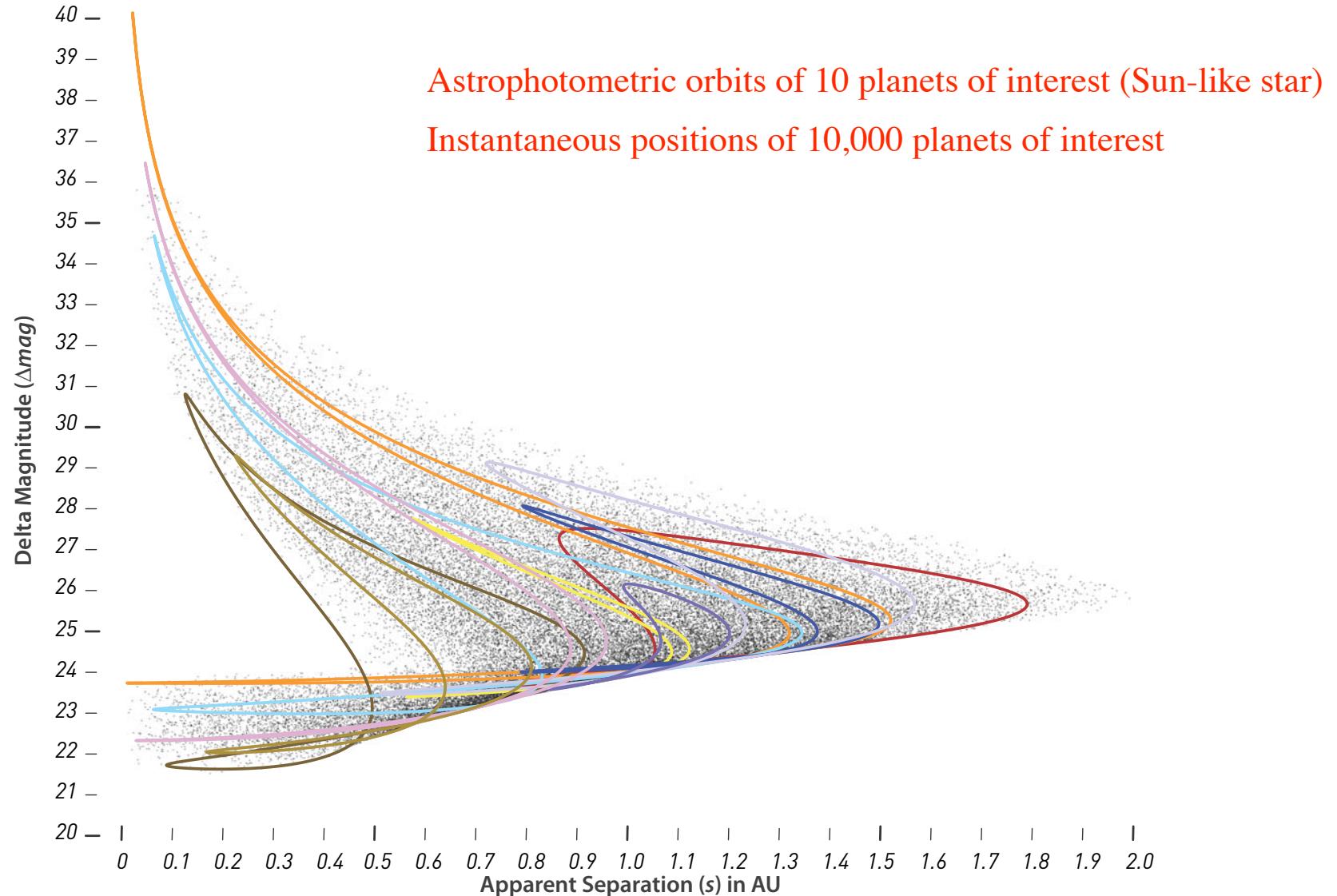
¹ The random deviate for θ is $\cos^{-1}(1 - 2R)$, where R produces pseudorandom numbers in the range 0–1.

² Lambertian phase function

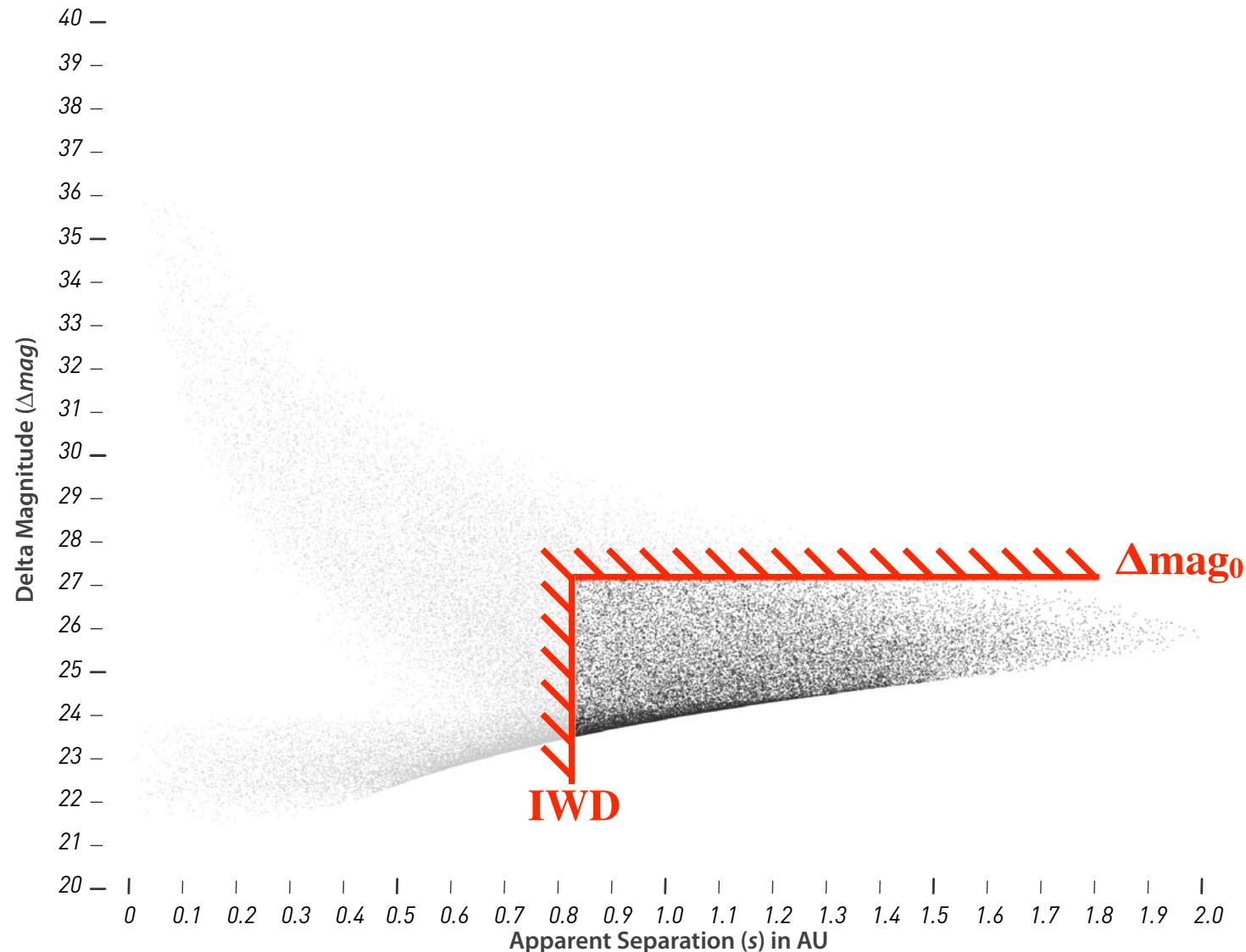
Monte Carlo planets



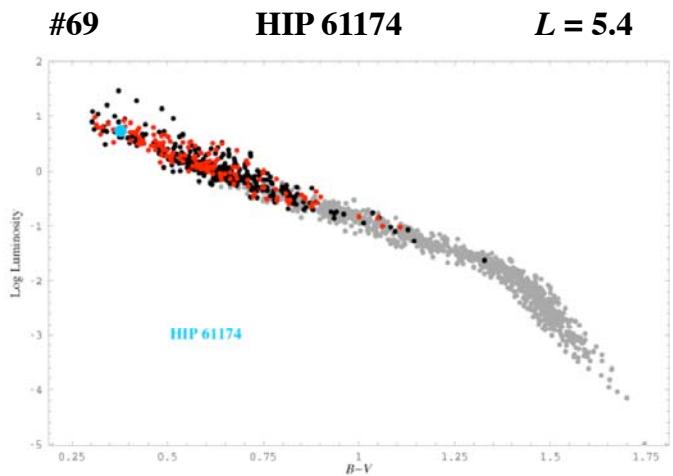
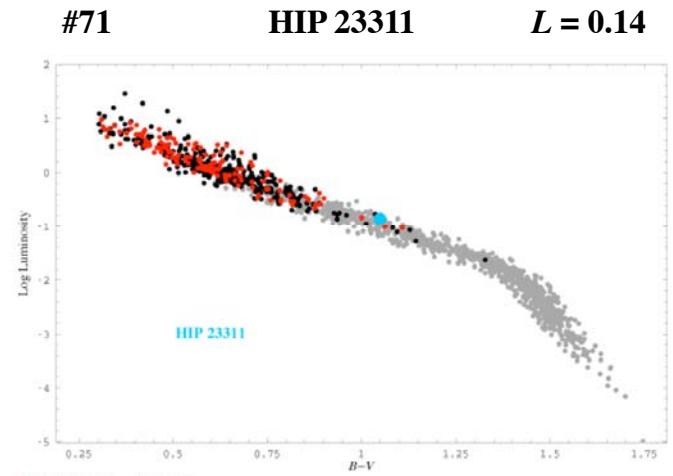
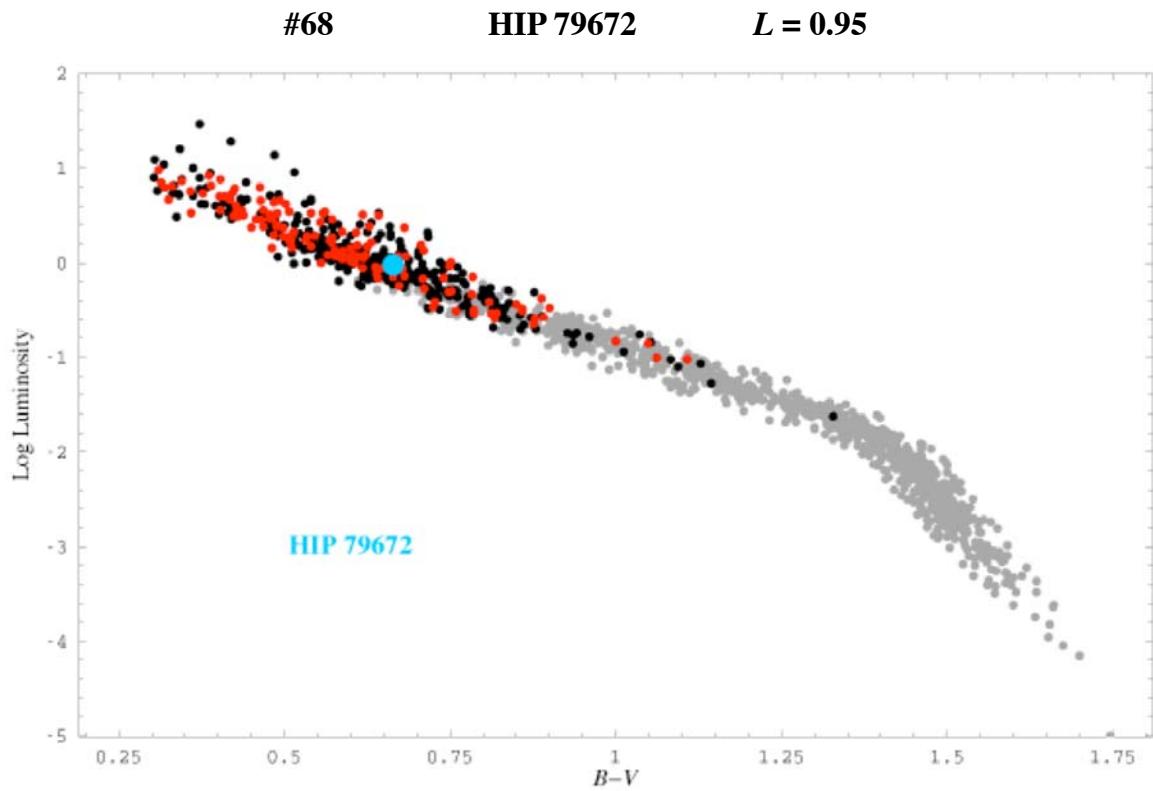
Monte Carlo planets



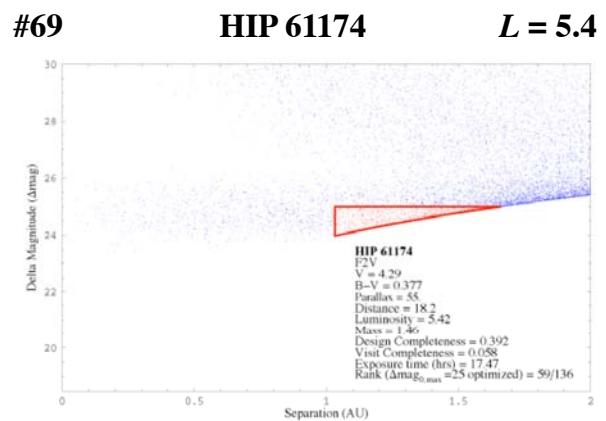
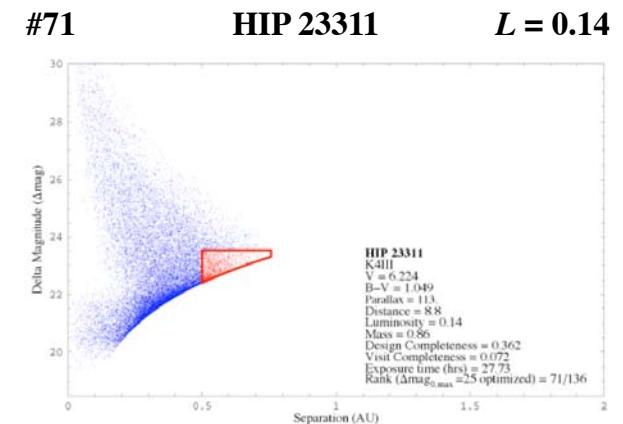
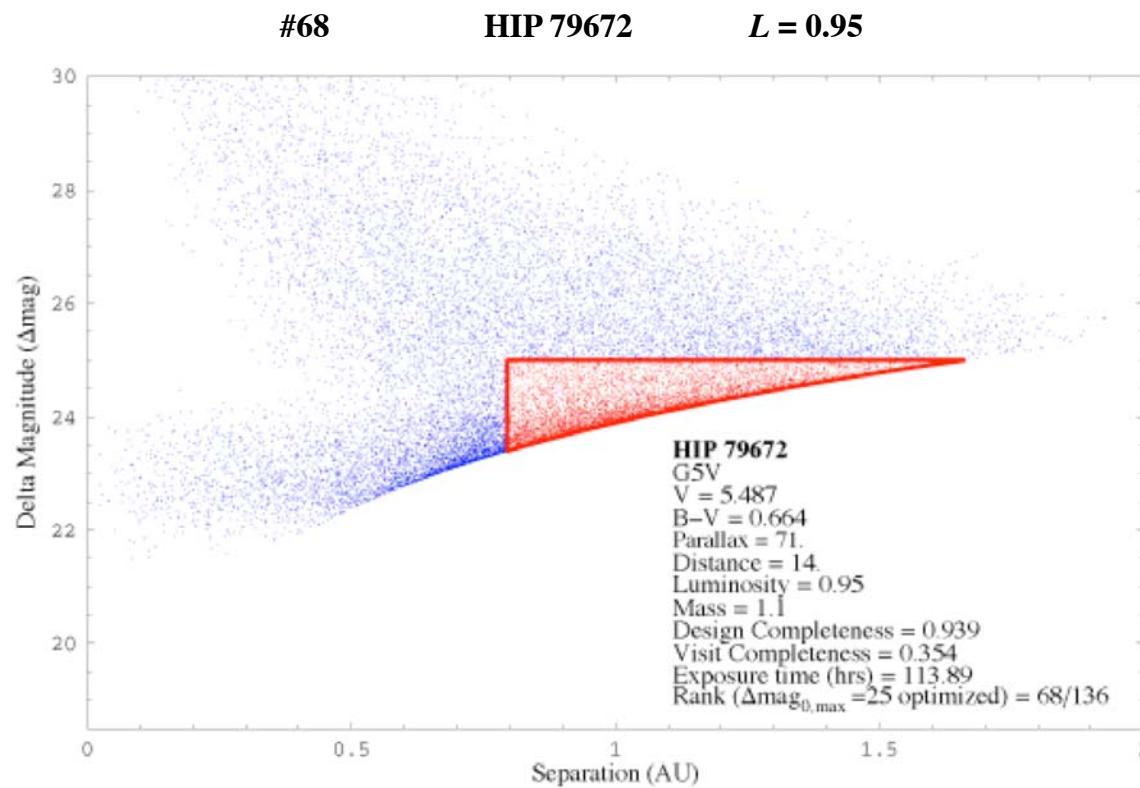
Completeness calculation & Monte Carlo sample



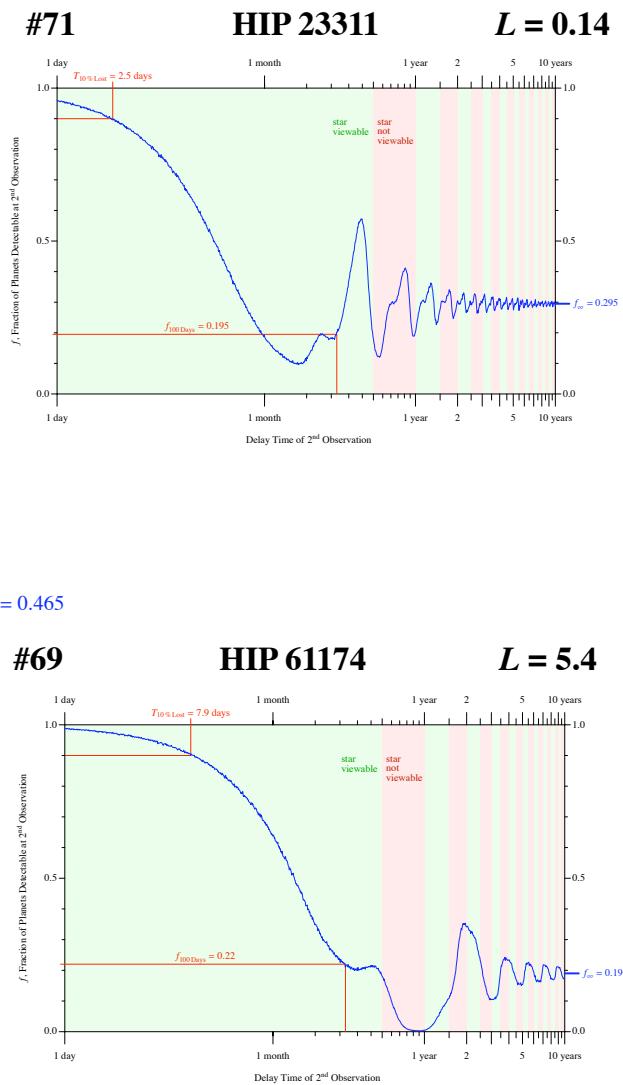
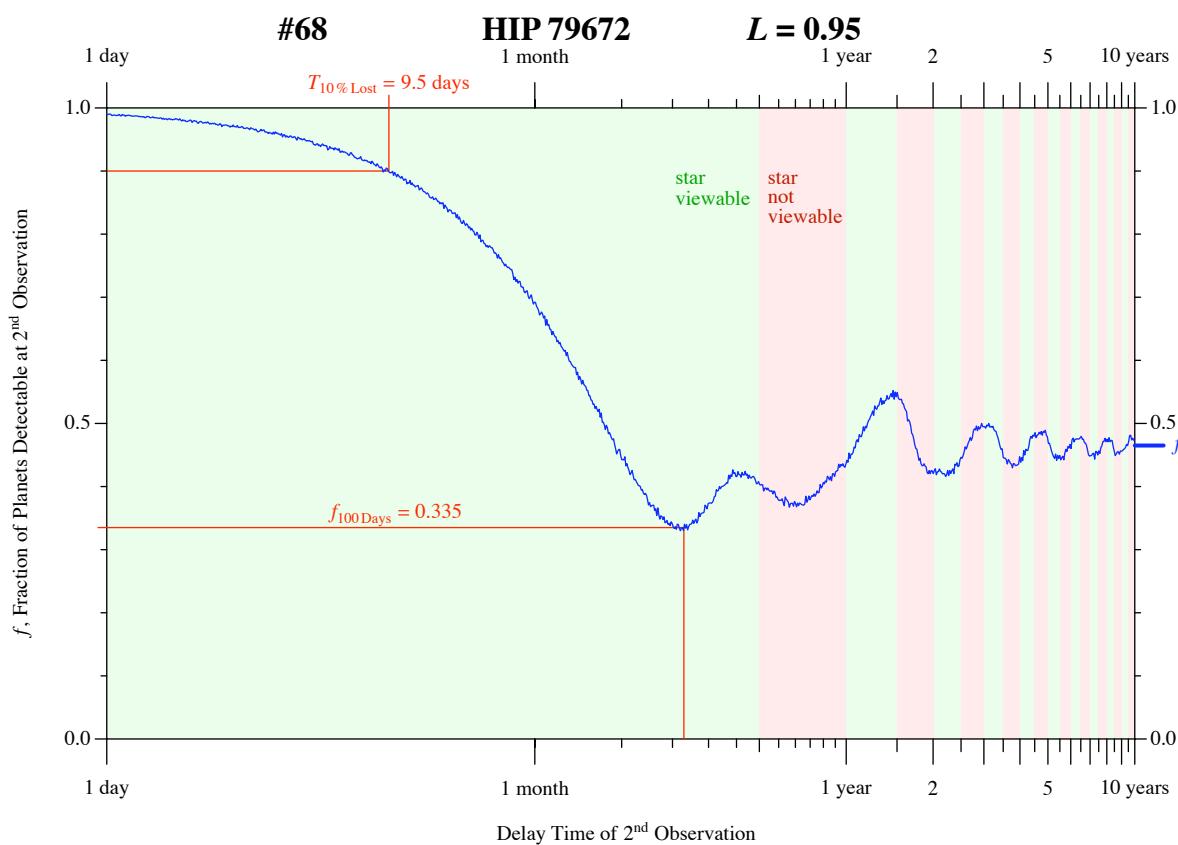
TPF-C Target Stars



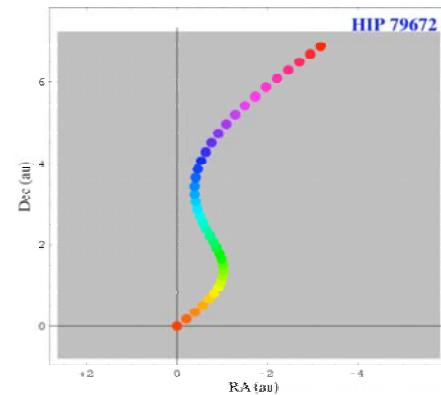
Monte Carlo sample of planets



Planetary Evaporation & Loss

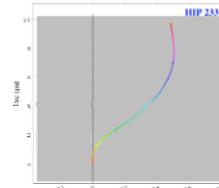
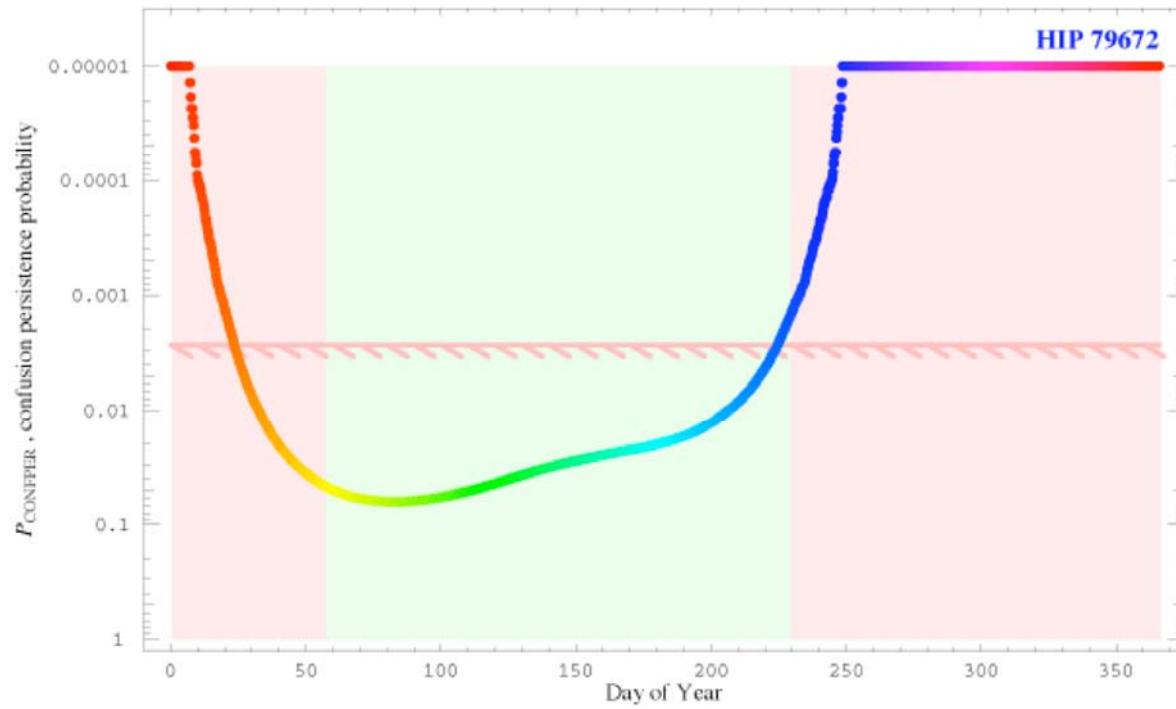


Solar Avoidance & Confusion Disambiguation



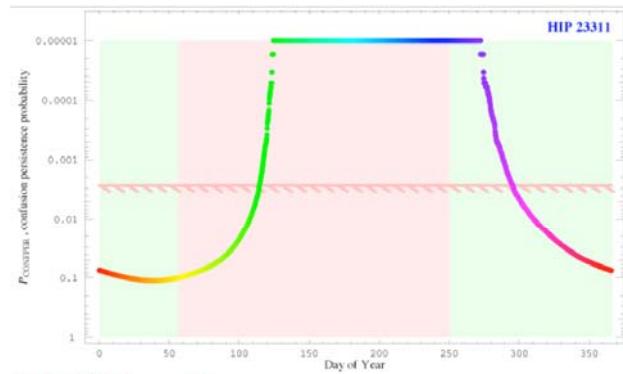
#68

HIP 79672

 $L = 0.95$ 

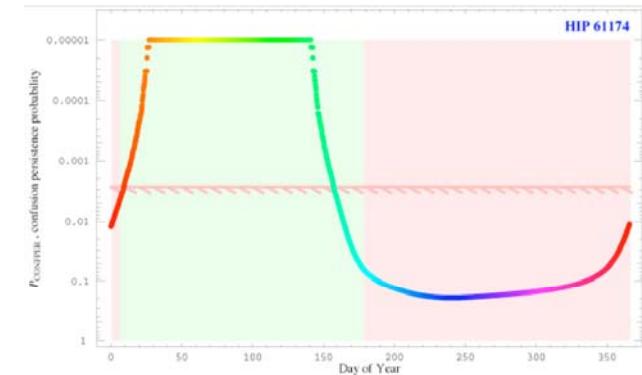
#71

HIP 23311

 $L = 0.14$ 

#69

HIP 61174

 $L = 5.4$ 

Disambiguation results

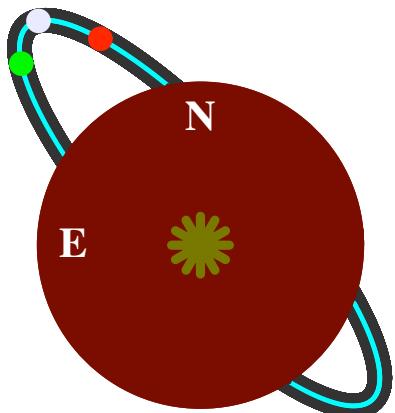
For terrestrial planets, astrometric disambiguation is:

- Never useful for 10% of stars, even with solar avoidance angle=0.
- Not useful for 33% of stars when star is viewable.
- Useful >20%, 30%, 40% of the time for 50%, 41%, 20% of stars

This problem goes away for jovian planets:

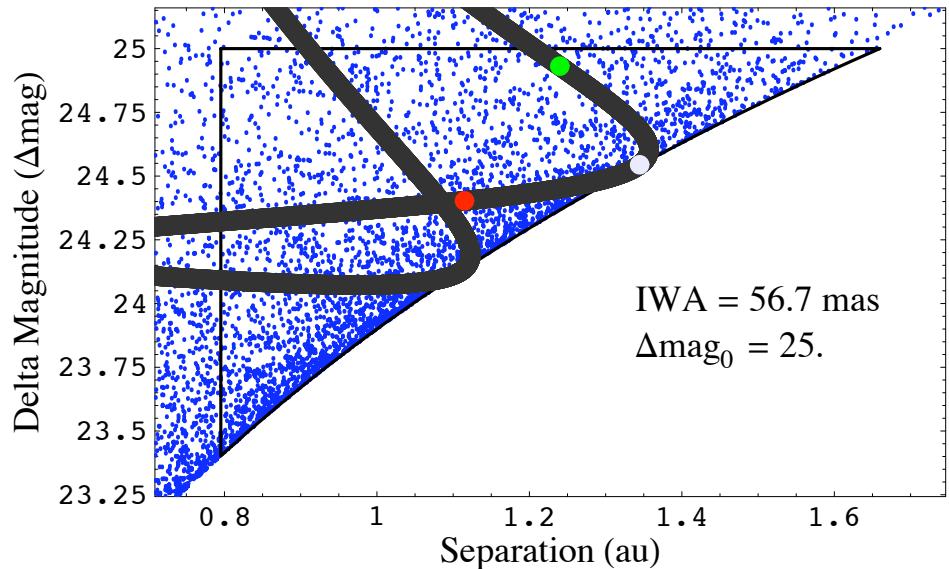
- planetary motions proportional to $1/\sqrt{a}$
- evaporation time increases with a

Close look at one typical planet of HIP 79672

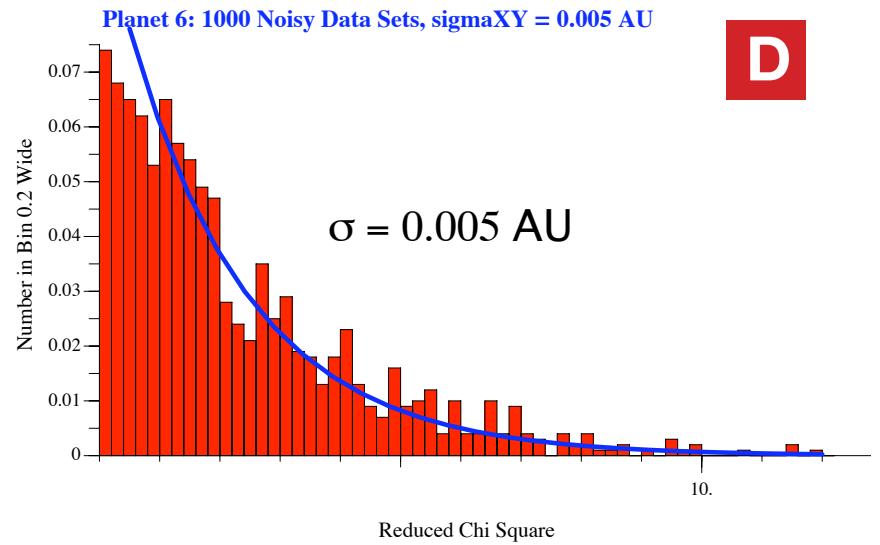
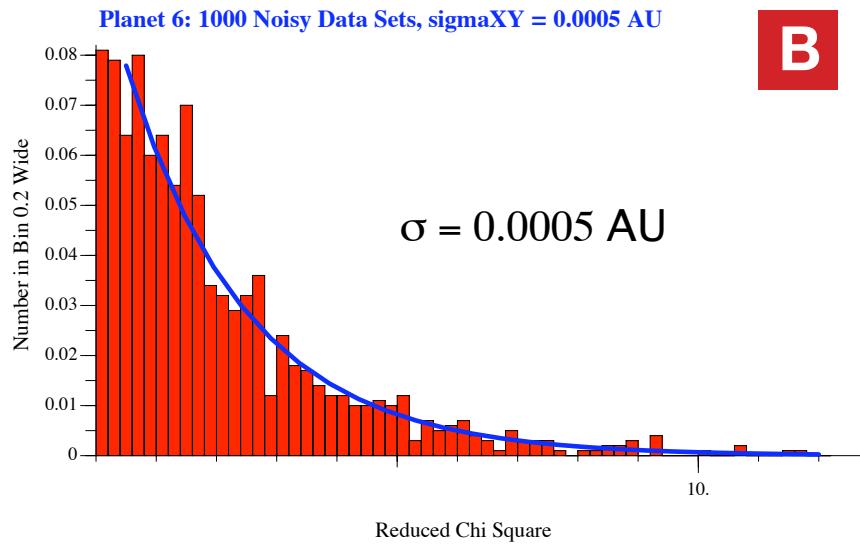
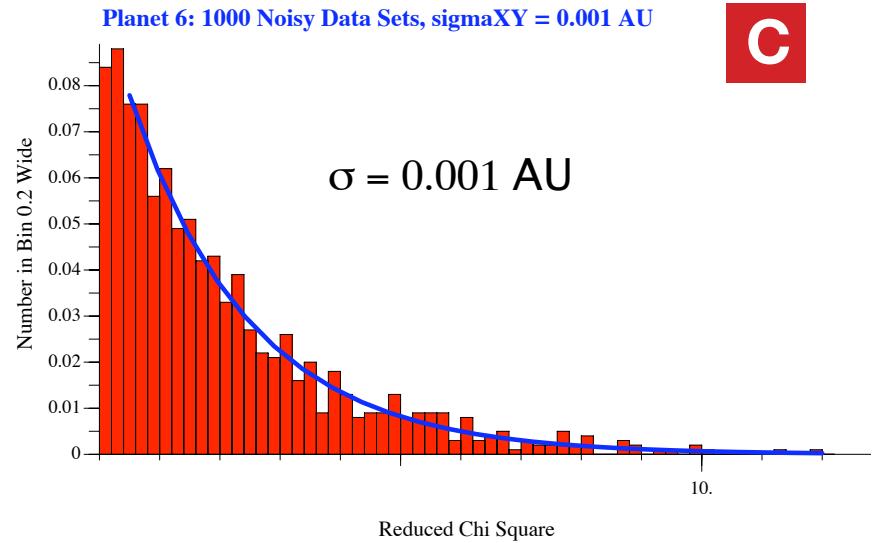
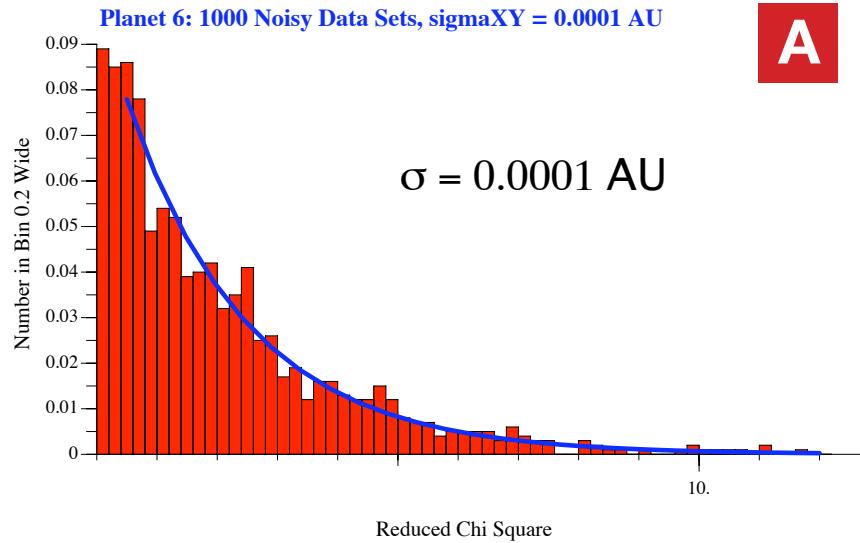


Fitted Orbit

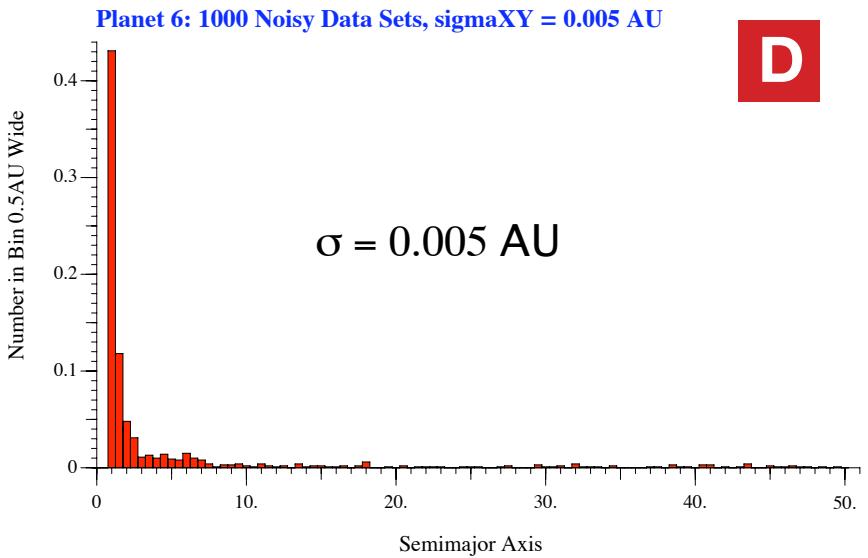
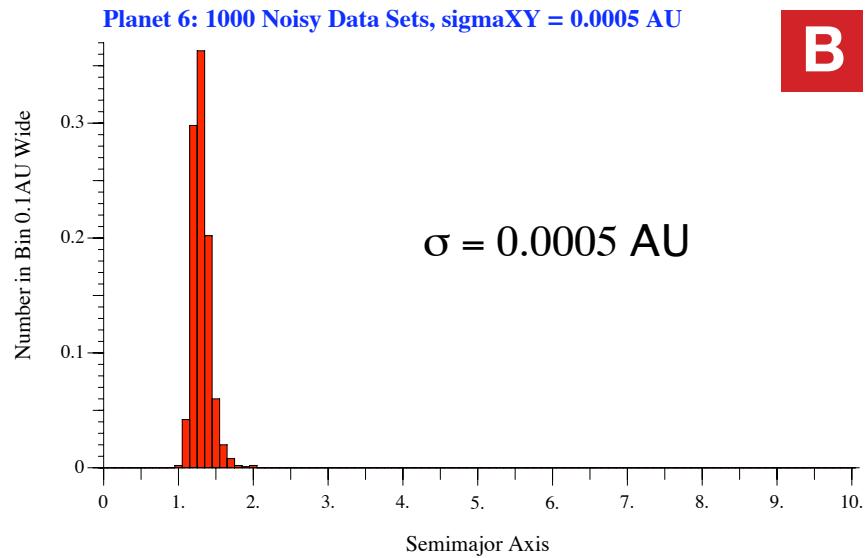
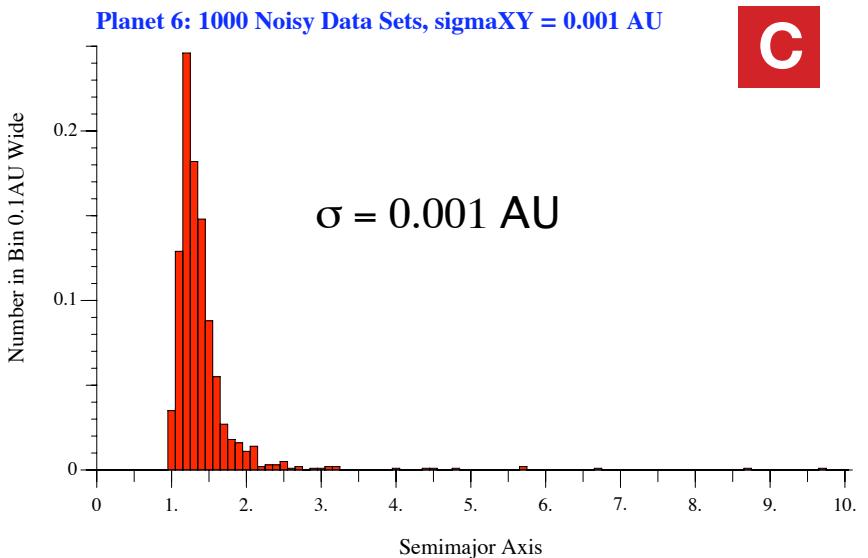
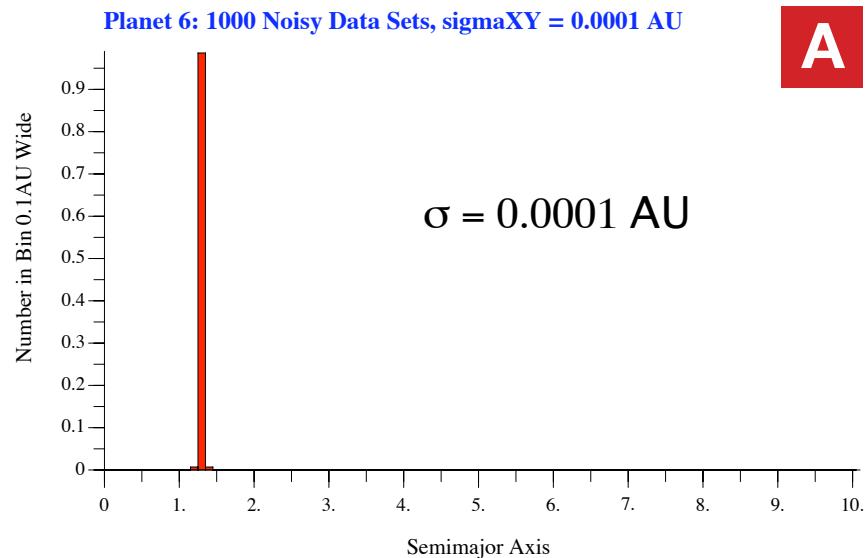
$a = 1.295$ au
 $e = 0.31353$
 $M_0 = 65.1$ deg
 $\omega = 73.3$ deg
 $i = 105.5$ deg
 $\Omega = 223.2$ deg
Period = 508.597 days
The orbit is retrograde



Chi squares for fits of four astrometric observations



Results for semimajor axis



Planetary recovery results

Accurate determination of a terrestrial planet's period from less than one cycle of observations requires astrometric accuracy far higher than 8m *TPF* is capable of.

-in typical case, four points in 100 days with $\sigma = 0.001$ AU produces 50% uncertainty in a or 75% in T .

It seems impossible for 8m *TPF* to reliably predict the future the future observability of a terrestrial planet after the epoch of its discovery.

This problem implies very inefficient observing program.

The problem diminishes for jovian planets because $T \gg 1$ year.
(Planet slow to move.)

References

Brown, R. A. 2004, “New information from radial velocity data sets,” *ApJ* 610: 1079–1092.

Brown, R. A. 2007 A, “Estimating planetary recovery from marginal astrometric data sets, Part 1. The critical case.”

http://sco.stsci.edu/tpf_min_scale/Part1_EstimatingPlanetaryRecovery_Printer_Version.pdf

Brown, R. A. 2007 B, “Estimating planetary recovery from marginal astrometric data sets, Part 2. Recovery & loss.”

http://sco.stsci.edu/tpf_min_scale/Part2_EstimatingPlanetaryRecovery_print.pdf